THESIS.

TEST OF THE ENGINE AND BOILER OF THE ELECTRICAL LABORATORY.

FOR THE DEGREE OF

B. S.

SCHOOL OF MECHANICAL ENGINEERING.

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TEST OF THE ENGINE AND BOILER OF THE ELECTRICAL LABORATORY.

The following results were obtained from a series of tests made on the engine and boiler of the electrical laboratory. The engine is one of the two engines in the dynamo room, and the boiler is in a separate building, which contains other boilers, used for heating purposes. There is a Stratton separator in the steam pipe six feet from the engine. It is made automatic in its working by means of a steam trap which is connected to the drip pipe. The exhaust steam is returned to the boiler-house where it passes through a Baragwanath feed-water heater. Both live and exhaust steam pipes are well protected with asbestos and hair-felt coverings. For convenience, the description of the tests are given separately.

Engine Test.

The engine is the Ideal, manufactured by A.L. Ide & Son, of Springfield, Ill. It is rated at 50 H.P. when set to run at 300 Rev. with 80 lbs. of steam. The engine and boiler tests were made at the same time. On account of the flange of the belt wheel being slightly deeper than that of the governor wheel, the brake was applied to the belt wheel and the flange utilized to hold the water to cool the wheel (See Plate 4.) The brake was of the ordinary Prony pattern, with blocks made of 3" x 9" maple and held together by a 1/8 x 3" wrought iron strap. It was lubricated by means of two oil cups supplied with good heavy engine oil, and also by lard applied from time to time with a small paddle. The water was supplied by means of a 1/2 " pipe reduced to 3/8 " and this made slightly smaller forming a 5/16" nozzle. The 3/8 " pipe was bent to follow the curve of the wheel so that the high rate of speed of the wheel would not spatter the water away from the rim. For an outlet, a 3/4" pipe was filed to a sharp edge and flattened on one side, and placed on the opposite side of the wheel from the inlet, where it scooped out the water. On account of the shallow flange and the small place left at each side of the balancing weight attached to the rim, it was difficult to keep the wheel cool after running for a few hours with a heavy load. The centrifugal governor worked efficiently. The reducing motion for the indicator was formed by screwing a standard to the cross-head and connecting with a pantagraph fastened to the floor. The ends of the cylinder were connected with the indicator by a three way cock. The tests were made in the usual way.

The areas of the indicator cards were measured with a planimeter and the indicated H.P. calculated by the well-known formula, H.P. = 2 R A S P ÷ 33,000. The brake H.P. was found by the formula, H.P. = speed of pulley rim x pull on rim ÷ 33,000.

The boiler and engine are connected by 125 ft. of 3 1/2 " pipe containing seven bends. On account of the long distance and the number of turns in the pipe the steam pressure would have to be carried at 110 lbs. at the boiler to get the full rated power from the engine.

The results of the tests are shown in Tables I, II, & III, and by the sample indicator cards in Plates I, II, & III. The efficiency of the engine is the ratio of the brake H.P. to the I.H.P. and was found to be 85.6 %! This gives an average engine friction of 14.4 %.

Boiler Test.

The tests were made on a Stirling boiler. No extended description is needed as there is a photograph of this type of boiler on Plate 6. It is of the water-tube safety pattern, having 54 tubes, 3 1/2 " in diameter. The principal data of the boiler are given in Tables 4, 5,& 6.

Two barrels were used in obtaining the weight of the water, the one on the scales being above the other so that the water would flow out. City water was used as no extra pump was at hand to draw water from the cistern. The feed pump had to be run with steam from the boiler that was being tested, as none of the other boilers carried a sufficient pressure. The suction tube of the feed pump was kept in the second barrel, so that the pump could be run at a constant speed.

The coal was weighed on platform scales in wheelbarrow loads. Before starting the tests the fire and ash-pit were cleaned, and at the end of the tests the fire and water gauge were brought as nearly as possible to the same condition as at the beginning of the tests. The ash in the pit was taken as refuse. No allowance was made for small particles of coal, because the grate bars were close. As the experimenters were not used to firing this style of boiler, the efficiency and capacity are probably less than an experienced person might have obtained (See Tables 4,5,& 6.)

In calculating the efficiency of the boiler, the heating power of Odin coal was taken at 12,663 B.T.U. per lb. of coal, as found by F. H. Clark, 90, in his Thesis experiments. Peabody's tables on saturated steam were used in our computations. The efficiency of the boiler was obtained by finding the ratio of the total number of heat units in the coal to those taken up by the water evaporated and was found to be 62.2 %.

Calorimeter Test.

In order to allow for the water carried away by the steam, we used the Barrus Universal Superheating Calorimeter. The later form of this calorimeter, as described in the Trans. of the Am. Soc. of Mech. Engrs. for 1890, was used. This consists of a chamber where a part of the moisture is deposited, and the remainder is evaporated by wire-drawing the steam through an orifice about 1/8 " in diameter (See Plate 7). At the lower part of the separating chamber is a drip cock and glass gauge. The steam was permitted to blow through the calorimeter continuously to keep it at a constant temperature. The water was brought to a mark in the glass guage at the start of the test and after a certain time the accumulation was drawn off. The temperature of the steam before and after throttling was read from two thermometers placed in brass cups filled with oil and surrounded by the steam. On account of the absence of apparatus, the steam blown through the orifice could not be measured and was therefore calculated by the formula, Q = 51.4 x Pressure above Zero x Area. The formula is taken from Barrus, the 51.4 being a constant found by experiment. Q gives the quantity in lbs. per hour. The per cent of priming was calculated separately for the water drawn from the separator and that shown in the superheating part.

The formula for priming shown by water in box is, Percent priming = Water in box ÷ Weight of steam. The formula for priming shown by the degree of superheating is, Percent priming = $[h + c(t' - t'') - q] \div r$. In which h = total heat, c = specific heat of steam, t' = temperature of steam as shown by lower thermometer, t'' = temperature of saturated steam at atmospheric pressure, and r = latent heat of steam at absolute pressure of boiler. The sum of these per cents gives the percent of priming in the boiler. This percent was subtracted from the total water pumped into the boiler, to find the water actually evaporated.

Referring to Tables 7,8, & 9 the % of priming is seen to be low. It would have been possible to dispense with the separator part of the calorimeter and only used the superheating part. The limit of use of the superheating part is about 3 % priming and our tests show an average of 1.96 %.

From the tests made at different pressures it was found that the boiler gave much drier steam when the pressure was high. If the pressure indicated by the gauge fell below 80 lbs. the boiler was apt to foam when more than 30 I.H.P. was developed by the engine.

Table No 1.

Card Number	Boiler Pressure	Revolutions of Engine	Mean Effective Pressure	Indicator H. P.	Initial Pressure	Boiler Less Initial Pressure	Brake Weight	Brake H. P.	Engine Friction
1	70	294	36.01	42.79	61.3	8.7	117	34.40	8.39
2	80	296	23.89	28.04	73.0	7.0	83	24.57	3.47
3	90	294	46.35	54.02	80.5	9.5	133	39.10	14.92
4	95	291	36.78	42.45	73.5	21.5	133	38.70	3.75
5	95	290	39.40	45.32	70.0	20.0	133	38.57	6.75
6	80	292	34.91	40.44	66.7	13.3	133	38.83	1.61
7	82	291	40.17	46.36	72.0	10.0	133	38.70	7.66
8	80	290	39.83	45.81	71.5	8.5	133	38.57	7.24
average	83.3	292	37.17	43.15	71.0	12.3	124.7	36.42	6.73

Table No 2.

Card Number	Boiler Pressure	Revolutions of Engine	Mean Effective Pressure	Indicator H.P.	Initial Pressure	Boiler Less Initial Pressure	Brake Weight	Brake H. P.	Engine Friction
1	83	293	39.00	45.32	62	21	133	38.97	6.35
2	82	290	36.84	42.20	56	26	133	38.57	3.63
3	82	290	38.58	44.38	60	22	133	38.57	5.81
4	88	293	36.72	42.68	66	22	133	38.97	3.71
5	86	291	47.56	54.90	66	20	168	48.89	6.01
6	88	293	39.84	46.31	67	21	133	38.97	7.34
7	68	292	32.40	37.53	55	13	117	34.16	2.37
8	75	296	31.62	37.13	64	11	117	34.63	2.50
9	92	292	38.40	44.47	69	23	133	38.84	5.63
10	83	290	36.84	42.39	61	22	133	38.57	3.82
11	79	293	35.37	41.11	62	17	133	38.97	2.14
12	88	291	36.72	42.38	66	22	133	38.70	3.68
13	80	294	36.45	42.56	65	15	133	39.10	3.46
Average	82.6	292	37.41	43.30	63	19.6	133	38.93	4.37

Table No 3.

Card Number	Boiler Pressure	Revolutions of Engine	Mean Effective Pressure	Indicator H. P.	Initial Pressure	Boiler Less Initial Pressure	Brake Weight	Brake H. P.	Engine Friction
1	97	300	11.29	13.43	73.5	23.5	34	10.20	3.23
2	98	298	22.41	26.48	76.5	21.5	74	22.05	4.43
3	97	293	31.33	36.41	74.5	22.5	114	33.40	3.01
4	100	292	42.97	49.74	80.0	20.0	136	39.71	10.03
5	106	292	44.15	51.12	83.0	23.0	136	39.71	11.41
6	103	295	41.79	48.90	82.0	21.0	136	40.12	8.78
7	75	290	34.38	39.54	55.5	19.5	104	30.16	9.38
8	106	296	38.76	45.49	81.5	24.5	136	40.25	5.24
Average	97.7	294.5	33.38	38.89	75.8	21.9	108.5	31.95	6.94

Table No 4.

Duration of test	6.75 hours
Temperature of feed water	198 °
Average pressure of steam	76.5 lbs
Weight of coal charged	2,154 lbs
Weight of water evaporated	13,200 lbs
Weight of refuse	296 lbs
Percentage of refuse	13.7 %
Weight of combustible	1,858 lbs
Evaporation per lb. of coal	6.1 lbs
Evaporation per lb. of combustible	7.1 lbs
Evaporation per lb. of coal from and at 212°	6.43 lbs
Evaporation per lb. of combustible from and at 212°	7.45 lbs
Grate surface	13.25 feet
Coal burnt per ft. per hour	16.2 lbs
Ratio of grate surface to heating surface	1 to 41.5

Heating surface	550 feet
Water evaporation per ft. per hour	3.56 lbs
Efficiency of boiler	56.5 %
Rated capacity	50 H.P.
Horse power developed by centennial standard	59.2 H.P.
Per cent. above rating	18.4 %
Kind of fuel	Du Quoin slack, hand fired

Table No 5.

Duration of test	5.75 hours
Temperature of feed water	206 °
Average pressure of steam	79.3 lbs
Weight of coal charged	1,945 lbs
Weight of water evaporated	10,803 lbs

Weight of refuse	231 lbs
Percentage of refuse	11.9 %
Weight of combustible	1,714 lbs
Evaporation per lb. of coal	5.55 lbs
Evaporation per lb. of combustible	6.30 lbs
Evaporation per lb. of coal from and at 212°	5.78 lbs
Evaporation per lb. of combustible from and at 212°	6.58 lbs
Grate surface	13.25 feet
Coal burnt per ft. per hour	25.5 lbs
Ratio of grate surface to heating surface	1 to 41.5
Heating surface	550 feet
Water evaporation per ft. per hour	3.4 lbs
Efficiency of boiler	52.2 %
Rated capacity	50 H.P.
H.P. developed by centennial standard	56.7 H.P.
Per cent. above rating	13.4 %
Kind of fuel	Mt Olive lump, hand fired

Table No 6.

Duration of test	2.5 hours
Temperature of feed water	208°
Average pressure of steam	96.5 lbs
Weight of coal charged	801 lbs
Weight of water evaporated	4,668 lbs
Weight of refuse	201 lbs
Percentage of refuse	25.1 %
Weight of combustible	600 lbs
Evaporation per lb. of coal	5.82 lbs
Evaporation per lb. of combustible	7.78 lbs
Evaporation per lb. of coal from and at 212°	6.07 lbs
Evaporation per lb. of combustible from and at 212°	8.12 lbs
Grate surface	13.25 feet
Coal burnt per ft. per hour	24.2 lbs
Ratio of grate surface to heating surface	1 to 41.5

Heating surface	550 feet
Water evaporated per ft. per hour	3.39 lbs
Efficiency of boiler.	62.2 %
Rated capacity	50 H.P.
H.P. developed by centennial standard	56.4 H.P.
Percent. above rating	12.8 %
Kind of fuel	Odin lump, hand fired

Table No 7.

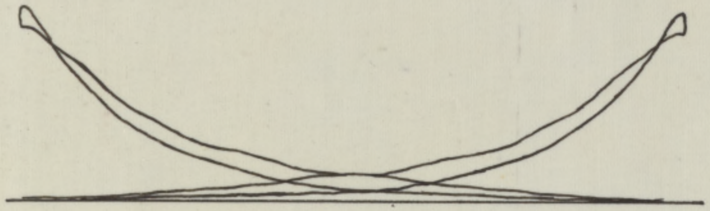
Time		Temperature		Water Drawn from Drip Box	Rate Per Hour Water Drawn from Drip Box	Boiler Pressure	Per cent. Moisture
Start	Stop	Upper	Lower				
2.00	2.15	157	133	64.2 grams	.254 kilograms	89	
2.30	2.45	—	—	—	—	—	Foaming
3.00	3.15	156	132	64.5	.258	85	
3.30	3.45	157	133	58.0	.232	81	
4.00	4.15	156	130	38.1	.152	78	
4.30	4.45	157	131	60.0	.240	69	
5.00	5.15	148	129	70.4	.281	73	
average		155°C	131°C	59.2 grams	.237 kilograms	79	2.06 %
		311°F	268°F	2.09 oz	.522 lbs	79	2.06 %

Table No 8.

Time		Temperature		Water Drawn from Drip Box	Rate Per Hour Water Drawn from Drip Box	Boiler Pressure	Per Cent Moisture
Start	Stop	Upper	Lower				
11.30	11.45	154.0	130.5	101.3 grams	.405 Kilograms	88	
12.00	12.15	154.0	133.0	110.2	.441	86	
12.30	12.45	153.0	133.0	84.6	.338	87	
1.00	1.15	148.0	129.5	73.8	.295	77	
2.00	2.15	156.0	134.0	95.8	.383	90	
2.30	2.45	153.0	132.0	75.1	.301	82	
3.15	3.30	148.5	130.5	74.1	.296	80	
Average		152.5°C	131.8°C	87.8 grams	.351 Kilograms	84.3	2.07 %
		316.5°F	269.3°F	3.09 oz	.774 lbs	84.3	2.07 %

Table No 9.

Time		Temperature		Water Drawn from Drip Box	Rate Per Hour Water Drawn from Drip Box	Boiler Pressure	Per Cent Moisture
Start	Stop	Upper	Lower				
10.45	11.00	161	135	50.6 grams	.202 kilograms	105	
11.15	11.30	148	128	55.3	.221	80	
12.00	12.15	159	135	59.8	.239	109	
average		156° C	132.6° C	55.2 grams	.221 kilograms	98	1.77 %
		313° F	270.7° F	1.95 oz	.487 lbs	98	1.77 %



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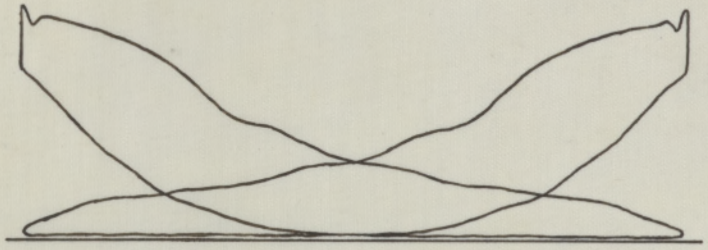

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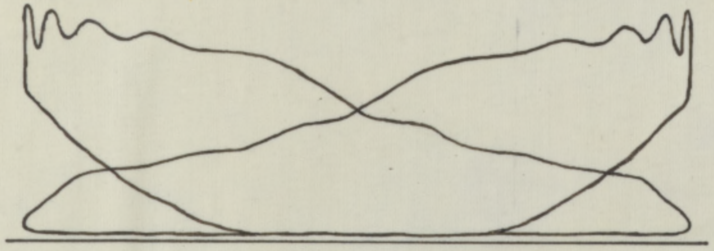

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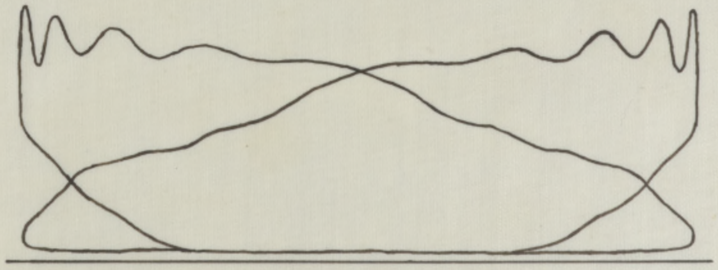

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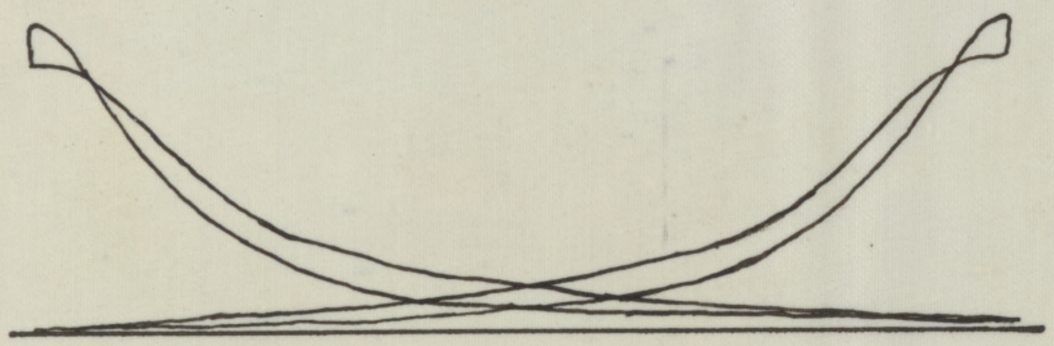

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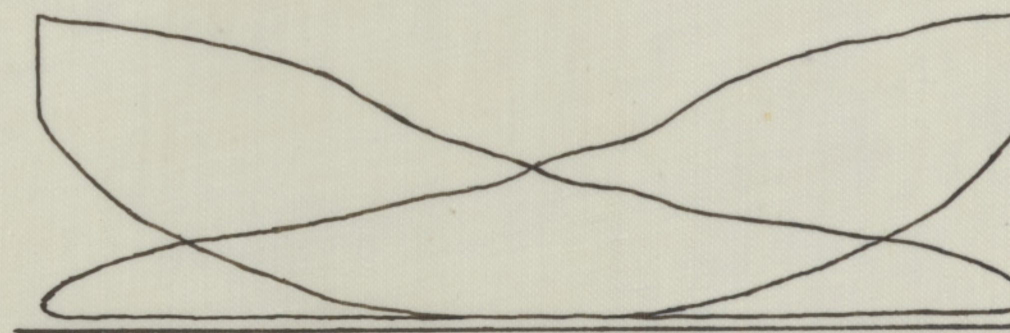

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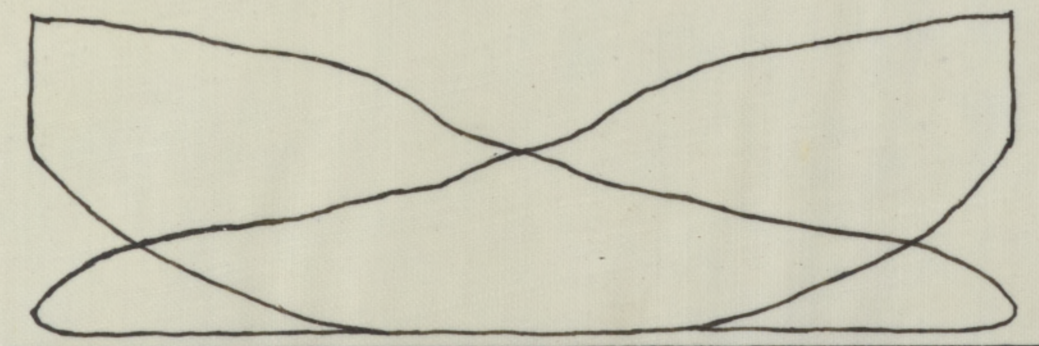

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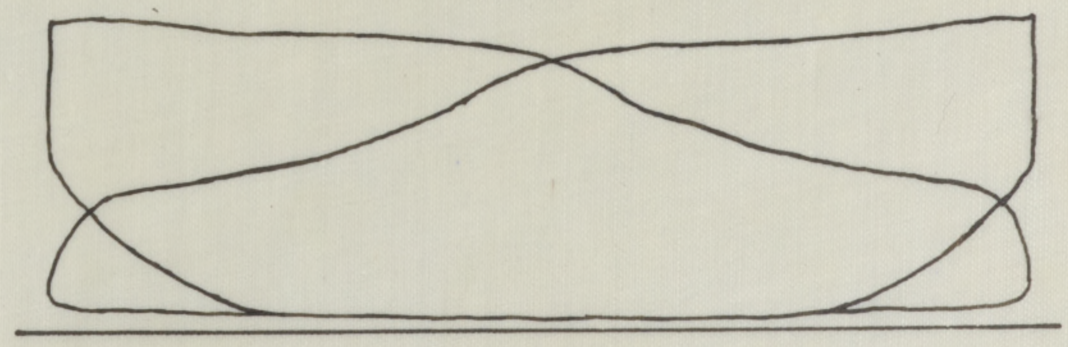

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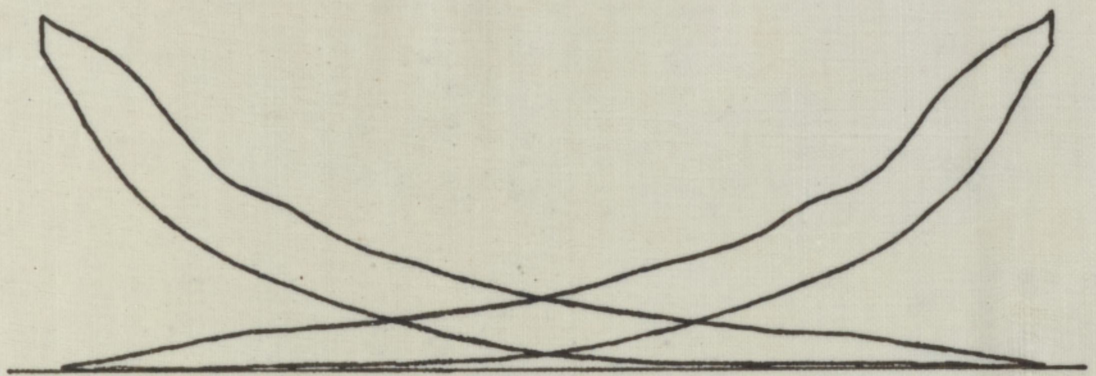

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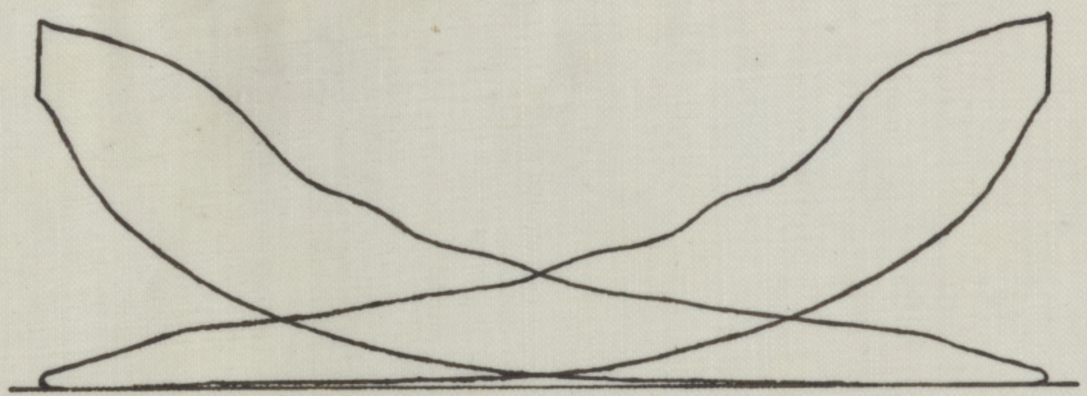

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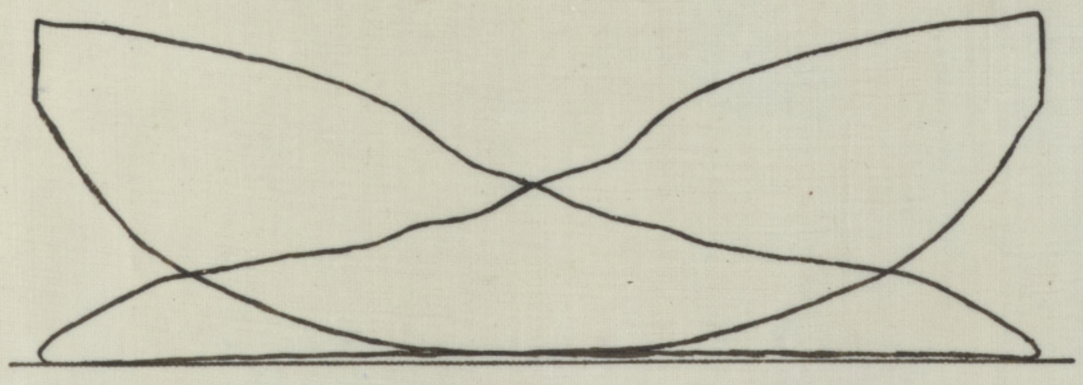

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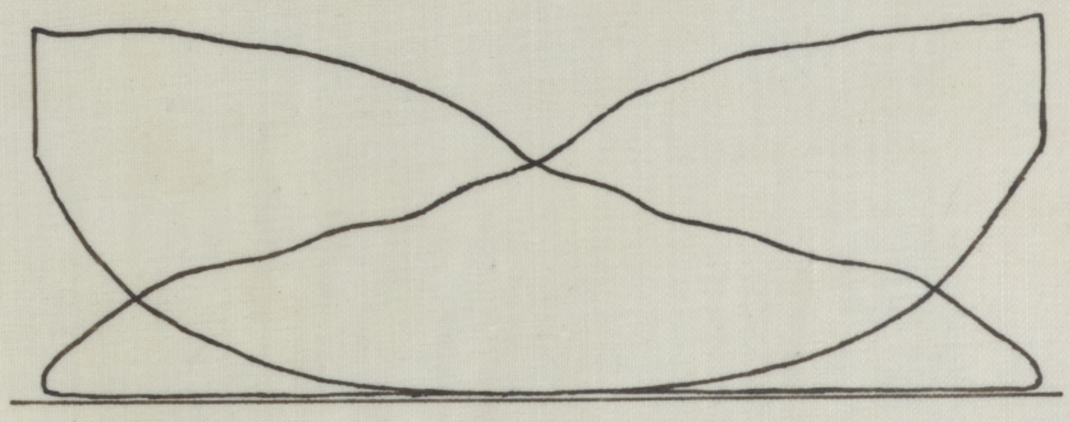

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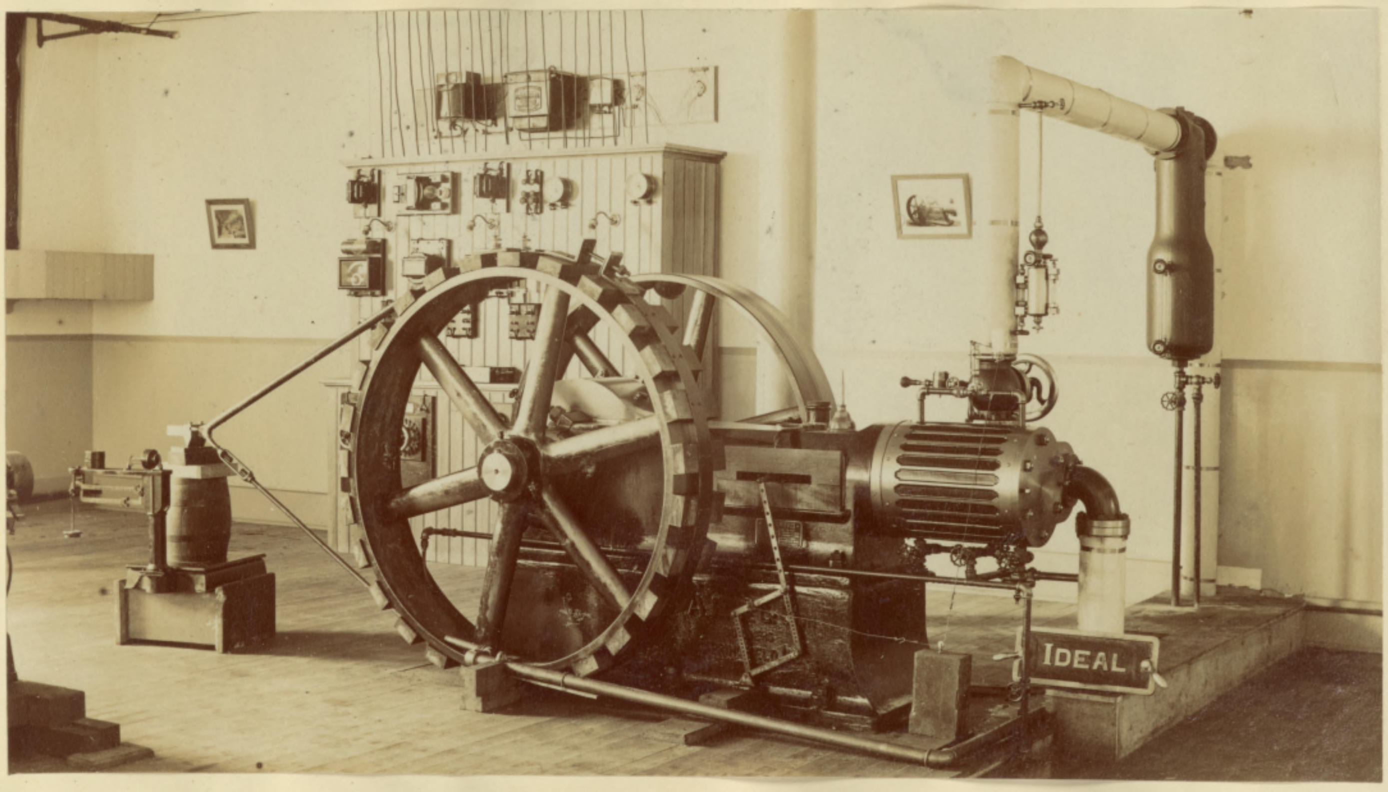

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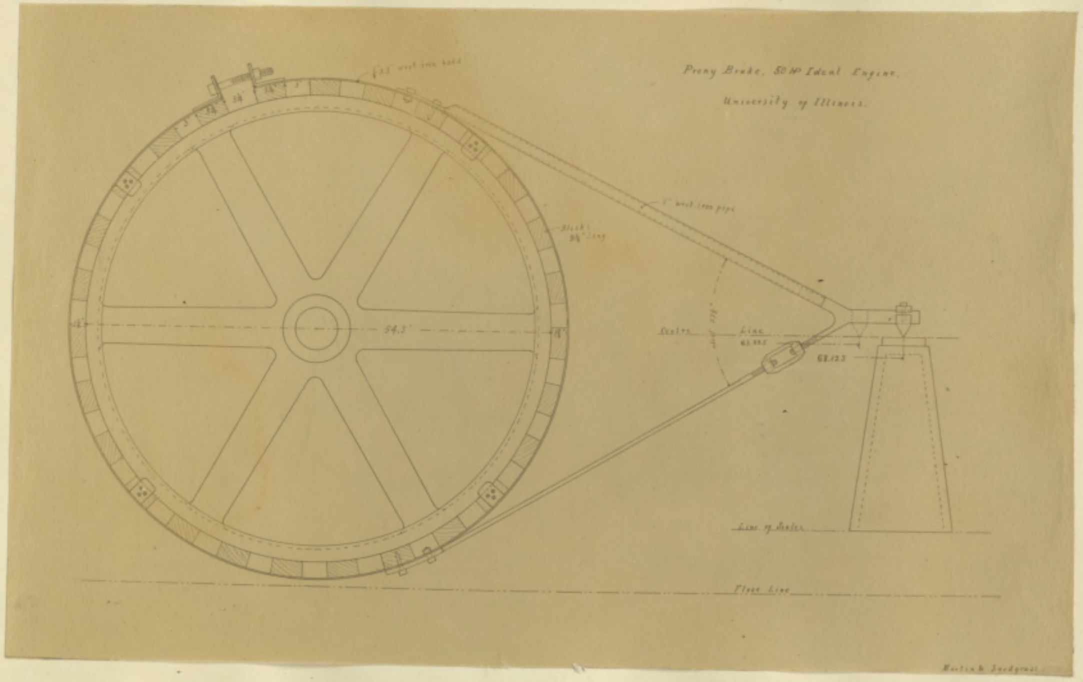
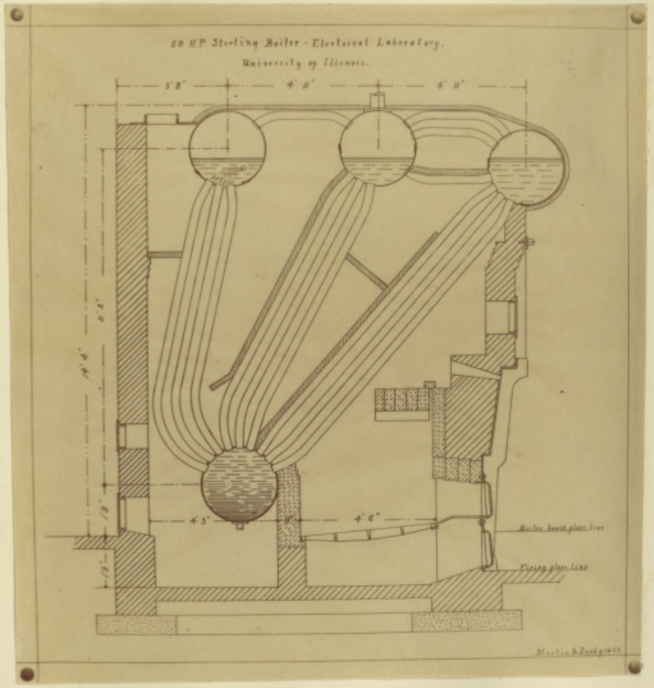


Prony Brake, 50 HP Ideal Engine.
University of Illinois.
Centre Line
Line of Scales
Floor Line

Plate No 6.



50 H.P. Sterling Boiler - Electrical Laboratory.
University of Illinois.
3' 2"
4' 8"
4' 8"
4' 5"
4' 6"
Boiler house floor line
Firing floor line
Martin & Snodgrass

Plate No 7.